SPECIAL ARTICLES, NOTES, AND EXTRACTS.

THE FUNDAMENTAL INTERVAL IN METEOROLOGICAL AND CLIMATOLOGICAL STUDIES, ESPECIALLY IN CHARTS OF ISOHYETAL LINES.

It is a well-recognized principle in meteorology that a comparison of averages for different countries, or for different parts of the same country, is liable to lead to erroneous conclusions unless we are careful to compare data for the same hour, day, year, or group of years. It is frequently difficult to do this because the records are fragmentary as to months and years and the observers have used such a variety of hours of observation. The labor of obtaining from broken records the approximate values proper to a continuous series of years is very great, and in fact distasteful to many climatologists, so that the published charts of mean values are often a collection of heterogeneous data that are not properly comparable with each other. The necessity of adopting and rigidly adhering to definite fundamental intervals when constructing a chart of rainfall was fully presented to our readers in the MONTHLY WEATHER REVIEW for April, 1902,[1] and the same principles apply to all other meteorological data. Interesting technical and historical details are given by Prof. Dr. George Hellmann in his exhaustive memoir on the precipitation of the watersheds of the north German rivers, published at Berlin in 1906.[2] In three large volumes Hellmann deals with about 4000 rainfall stations; the available records begin with one station in 1701 and end with 3672 stations in 1890. He adopts 1851–1900 as the fundamental interval or base period for all his studies and charts.

The records can not be combined into one perfectly satisfactory system because the observers have had different points of view in mind. Some have paid attention to heavy rainfalls, others to both light and heavy equally. Some have recorded the depth of snow in inches and others the depth of the equivalent water. Some have recorded the number of days of precipitation above an arbitrary lower limit, say one millimeter, others have recorded the slightest possible sprinkle. Some have measured by weight, others by volume, others by depth of rainfall. The total collected material must therefore be divided and studied according to the individual peculiarities of the observers and their records. Hellmann says "the correctness of these rainfall tables depends upon the view that is taken of the precipitation, and strange as it may seem there scarcely exist anywhere in meteorology data that are less reliable and less comparable as to uniformity than those of precipitation. The individual views, the accuracy, and the mode of life of the observer play an important part, and these personalities can only be excluded by the uniform introduction of self-registering apparatus of uniform type and delicacy."

STYLE OF GAGE.

In his efforts to reduce all his data to a uniform system of intercomparable averages, Hellmann begins with a study of the influence of the shape and construction of the rain-gages themselves. With regard to this point he states that the oldest gages consisted of a simple receiving cylinder. The precipitation evaporates so easily from these gages that the greatest attention on the part of the observer is necessary; the rainfall must be measured without delay, and falls of one-hundredth of an inch are quite often not measured but lost. Moreover, the gages were so shallow that the snow was always liable to be whirled out of them.

An item that especially interests us is Hellmann's account of the conical gage which was used by the physicians Kanold and Kundmann, of Breslau, in 1717 to 1727, and which was originally described with drawing at page 160 of the Sammlung von Natur- und Medecin- . . . Geschichten. Sommer Quartal 1717. Breslau 1718. Quarto. Page 160. Hellmann states that before knowing of the work of the Breslau physicians he had himself modified his own rain gage of 1886 in an analogous manner, allowing the vertical cylinder to terminate below in a cone, so that the first part of a very slight rainfall could be measured most accurately.

A conical gage was introduced to American observers by Simeon De Witt about 1807, and is described by him in the American Journal of Science. We had always supposed this to be an American invention until historical research brought to light this older German usage.[3]

Altho the older authors describe clearly the conical mouth of the gage, with the various additional devices for measuring the catch, yet the method of weighing rather than measuring the rainfall seems to have been the favorite at all the early German stations. The use of a special small graduated glass cylinder was introduced much later.

EXPOSURE OF RAIN GAGE.

With regard to the exposure of the rain gage Hellmann justly remarks that this is vastly more important than any peculiarities of instrumental construction. The diminution of rainfall with altitude was known for a century before it became clearly understood that this apparent diminution of rain is purely an instrumental error due to the influence of the wind at the mouth of the rain gage, and Hellmann claims for himself the important conclusion that it is wrong to require that rain gages shall be placed on or near the ground and be exposed as freely as possible to the wind. This discovery is of more importance now that our rain gages are so often placed high above the ground, whereas formerly they were in protected spots in gardens or farms. Hellmann properly states that no general law for the conversion of the catch of the gage into true rainfall has yet been found. We think, however, that if several gages of the same type are similarly placed (e. g. upon posts), in the same locality in an open field, at different heights above ground, the differences in their records should give us the means of approximately correcting for the wind effect. In the protected gages of Joseph Henry (1853), F. E. Nipher (1878), and R. Boernstein (1884), as well as in the protected gages established by Hellmann in the centers of depress roofs or protected by battlements, we attain results that are very nearly independent of the wind. The rule that rain gages should be established one meter above the ground in Europe, or one foot above the ground in Great Britain, should be supplemented by the rule that they must also be protected from the wind. Hellmann quotes the results of observations in Germany, in 1896, showing that they agree with those made elsewhere in proving that the difference between gages at the ground and at one meter

[1] Vol. XXX, p. 205–243.

[2] See Monthly Weather Review for July, 1906, Vol. XXXIV, p. 328.

[3] Hon. Simeon De Witt was born about 1755 and died at Ithaca, N. Y., December, 1834. He was for a long time surveyor-general of the State of New York, and was also one of the regents of the university. He published many contributions to knowledge and was a man of strong character and great influence. In an obituary notice Prof. Benjamin Silliman says: "The Hon. Simeon De Witt was an eminent patron and cultivator of useful knowledge, and himself possessed high scientific attainments, especially in astronomy, engineering, and general physics. We deeply lament his loss, not only as a friend of science, but as a pure patriot, a zealous and indefatigable public officer, an estimable citizen, and an honest man". (Amer. Jour., Sci., Vol. 27, 1834, 395.)

In 1807 De Witt read before the Albany Institute (see Vol. 1, page 60 of its transactions) a description of an elaborate conical rain gage; but as this was costly in construction, he afterwards (May 3, 1832) described a much simpler and cheaper form, known as "De Witt's 9-inch conical rain gage," and gave examples of the records made with it during April and May of that year (see the American Journal of Science and Arts, vol. 22, p. 321–324.)

There is no certain evidence De Witt had any knowledge of the conical gage used by Kanold and Kundmann in 1717–1727, but it is not impossible that he may have heard of this device for measuring small rainfalls thru mention of it in some of the numerous works that were accessible to him at Albany and Ithaca.—EDITOR.

above the ground is 6 per cent, and diminishes regularly with altitudes. He also shows that the diminution is greatest in cold months.[4]

ANNUAL VARIABILITY.

On page 37, of this volume, Hellmann takes up the question of the reliability of any mean annual rainfall so far as that depends upon the variability of the weather from year to year, showing very plainly that only the means that are based upon many years of observations, and as far as possible on simultaneous records, can lead to reliable results as to the geographic distribution of rainfall. His study, moreover, shows us how mean values deduced from shorter periods may be utilized to this end. The first step is to secure a long series from several stations—he quotes 14 for which he has records for fifty years or more. For each of these the mean is taken for each period of five, ten, twenty, thirty, and forty years for comparison with the mean for sixty years. The differences show us that for the German stations the mean of any five years will differ by 5 or 10 per cent from the mean of any other five; that the variability of the mean annual rainfall increases decidedly as we go inward from the ocean; that the range of the average of twenty years may be from 15 to 30 per cent of the total rainfall; that in order to obtain a rainfall average that is correct to within plus or minus 2 per cent we must have a complete record of at least thirty and in many cases over forty years. These statistical studies in accordance with the method first published by Koch, in 1887, and Blanford, in 1892, if applied to the more variable climate of the United States would undoubtedly require us to wait until we have fifty years of observations under uniform exposure of the rain gage before attributing to its mean records an accuracy of plus or minus 2 per cent.[5]

On page 41, of Hellmann's memoir, is given an equally important study relative to the frequency of dry years and wet years. If we convert each annual rainfall at Gütersloh from millimeters into a corresponding percentage of the normal annual rainfall and then out of the 64 years of record pick out the ten wettest years and again the ten driest, we find the average precipitations to be 124 and 73 per cent, and the difference between them is 51 per cent of the normal rainfall. If only one could foresee when these extremely wet and dry years would occur. But, as yet, this is as impossible for Europe as it is for America.

REDUCTION TO THE FUNDAMENTAL PERIOD.

There were only 109 stations available to Hellmann for computing annual average rainfalls for his fundamental period of fifty continuous years preceding 1900, and these stations are not sufficient to form a reliable rainfall chart of Germany. He, therefore, set himself the problem of reducing the shorter and fragmentary series to what they would have been if continued during the whole of this fundamental period. In this connection he states, on page 42, that according to the Annuaire of the Meteorological Society of France[6] the hydraulic engineer, Fournié, in 1864 first established the rule that the ratio of the annual rainfall at neighboring stations is nearly constant from year to year, but that this is not true for stations far apart, and this principle was long used by the engineers before it was adopted by the meteorologists. In 1872 J. Karsten discust the question whether the method used for reducing mean temperatures to a common basis and to a normal station could not also be used for rainfall. In studying the rainfall Karsten used the differences between neighboring stations, rather than the ratios, and found fairly good results, but only when the rains were uniformly distributed and when extreme values were rejected and when the stations were very near and under similar influences. He found that in summer time heavy local thunderstorms disturbed all such relations. In 1880 Hann, and in the same year, also, Hellmann himself modified and made use of Karsten's idea. The fundamental basis of Karsten's method is the assumption that the great variations of rainfall occur simultaneously over broad regions. The same principle has been adopted concerning temperature for many years past, but temperature is much more regular than rainfall. Before applying Karsten's method Hellmann studied the ratios of pairs of stations that are only one, two, or three kilometers apart, as is done in Fournié's method, and finds that the ratio, which should be unity, actually varies between 1.144 and 0.930 in the forty-four cases that he cites for four stations. These stations were chosen because the rain gages were alike and with the best exposures, but if the gages have bad exposures the ratios are much more variable and irregular, and so also if the gages are at greater distances apart. The irregularities are also, of course, increased whenever there is any change in the homogeneity of the series due to a change of gages, exposures, hours of observation, or observers, so that by studying the relation between the records of two stations we can even ascertain the value of the different parts of the long series. On page 46 is given a very important table showing year by year the ratio between the respective annual rainfalls, as also the departures of these ratios from their average values for four pairs of stations, which are separated from each other, approximately, as follows:

Station.	State.	No.	Lat. N.		Long. E.		Altitude.
			°	′	°	′	*Meters.*
Berlin	Brandenburg		52	30	13	23	32
Torgau	Sachsen	593	51	34	13	00	99
Cologne	Rheinland	346	50	56	6	57	60
Bonn	Rheinland	345	50	44	7	6	56
Geissen	Hesse	298	50	10	9	21	203
Frankfort, a. M.	Hesse	281	50	7	8	41	104
Gütersloh	Westphalia	48	51	54	8	23	77
Lingen	Hannover	51	52	31	7	19	25

Berlin south 5° west 120 kilometers to Torgau.
Cologne south 30° east 30 kilometers to Bonn.
Geissen south 2° east 55 kilometers to Frankfort.
Gütersloh north 45° west 100 kilometers to Lingen.

The ratios of the annual rainfalls of these stations vary between 1.43 and 0.75; that is to say, one station of a pair has a rainfall that is sometimes 43 per cent above and at other times 25 per cent below the rainfall for the other station. The oscillations of the ratio may be as large as 67 per cent for one pair, viz: Berlin-Torgau, but the amount is only 47 per cent for the best pair, viz: Gütersloh-Lingen. The ranges do not depend simply upon the distances of the stations apart. Even if we compute the ratios not for individual years, but for the lustra or five-year periods, still they have a very large range, as is shown by tables for twelve different groups of stations; so that in general neither individual years nor individual lustra can profitably be reduced to the means for the fifty-year fundamental epoch.

In order to determine more exactly the influence of the distance from each other of a pair of stations the records for Berlin were compared with those for twenty other stations located at distances of from 94 to 655 kilometers, most of them, however, stretching in a belt from east-northeast to west-southwest, nearly parallel to the coast of Germany and Holland. The average departure of each annual ratio from its mean value increases from 12 per cent for the nearby stations

[4] Various interesting details on this subject will be found in an article written by the Editor in 1887, and printed in the Monthly Weather Review of October, 1899, Vol. XXVII, pp. 464–468.

[5] The errors of short-period rainfall registers in the United States were briefly discust by Prof. A. J. Henry, in Weather Bureau Bulletin D, (1897), p. 9. For the eastern coast of the country the possible error of a ten-year period was found to be 16 per cent of the normal annual amount; for the interior valleys 17 to 20 per cent; and for a Pacific coast station only 10 per cent. The conclusion reached by the author was that at least thirty-five or forty years of observation are necessary to obtain a result that will not differ more than plus or minus 5 per cent from the normal.

[6] See the Annuaire for 1865, p. 20.

up to 18 per cent for the more distant ones; the results being charted show that in north Germany it will always be advantageous to reduce the precipitation for any station to the fundamental period by using stations to the westward as normal stations.

The limit of the error introduced by reducing mean rainfalls for a short period to those belonging to the fundamental period is worked out by Hellmann according to a method that he applied in 1875 for the reduction of French observations, and he concludes that his isohyetal chart for 1851–1900 is liable to be in error in some places by from 8 to 12 per cent of the local rainfall when the local stations have only ten or fifteen years of observations, but by less than 5 per cent when thirty years of records are available.

ANNUAL PERIODICITY.

The annual periodicity of the rainfall is based upon monthly means from all stations for which there are over 35 years' records. Here again we have to face the fact that the monthly means are not comparable among themselves, owing to the various lengths of the months, and some correction must be made before we can ascertain precisely the character of the annual periodicity. The difference between the 28 days of February and the 31 days of some other months is equivalent in fact to 10 per cent of the monthly rainfall. Hellmann prefers to express the monthly rainfalls as percentages of the total annual for each locality without making other theoretical corrections. Renou reduced the rainfalls for any calendar month to its value for a month of normal length, namely, 30.42 days; H. Meyer reduced each month to an equivalent for 30 days; Quetelet and Kreil adopted the quotient of the number of days of rainfall by the number of days in the month, and ascribed the average daily rainfall to that day of the year or that longitude of the sun that corresponded to the middle of the month. Even Angot's method of relative excesses or his pluviometric coefficients (apparently due to Renou) only imperfectly overcomes the irregularity due to the unequal lengths of the months. Hellmann points out that all these methods lead to the same result if instead of actual rainfalls we use monthly rainfalls exprest as percentages of the total annual. In his lithographic Plate No. 1 [not reproduced] he gives the annual curves of percentage of precipitation for all of his 35 and 50-year stations, about 90 in all.

The distribution of rainfall in Germany by percentages for the four seasons—winter, spring, summer, and autumn—brings out clearly the contrast between continental and oceanic influences, and this is summarized in Hellmann's figure 7, page 82, which shows the percentage of precipitation in the colder half of the year, October to March, exprest as a percentage of that which falls in the warmer half of the year, April to September. Thus for Bonn, on the average of fifty years, 41.8 per cent of the total annual precipitation falls in winter and 58.2 falls in summer. The lines of equal winter percentage show a steady diminution from 50 per cent in the northwest toward 30 per cent in the east and southeast. Thus in the valley of the lower Rhine the precipitation is evenly divided between winter and summer, but in the valley of the upper Oder the summer rainfall is almost twice that of the winter. These relative quantities of rainfall and snowfall are the vitally important factors in all studies of forestry, agriculture, and hydraulic engineering, and, as the Editor has pointed out, in glacial climatology also. Similar studies applied to the Nile, the Mississippi, and the great rivers of India and China have a direct bearing upon broad problems of internal navigation and irrigation.

Hellmann's maps on page 84, showing the months of heaviest and lightest rains, depict the region of heavy rains moving northward into Denmark; the month of September appears unimportant, whereas meteorologists have generally stated that this is the month of maximum rainfall in Schleswig-Holstein, an error that seems to have arisen from the study of various short series of observations. The annual movements of the areas of heaviest and lightest rainfall are not explicable by any study of the movements of the areas of high and low pressure.

As we may determine daily mean temperatures from the daily maxima and minima, so Hellmann studies to what extent we can determine the annual rainfall from the records of the three driest and three wettest months. With the assistance of W. Meinardus, who examined about thirty different stations from this point of view, he has discovered that the principal features of the annual rainfall are analogous to those of the wettest and driest months, so that there is a nearly constant ratio between the mean annual rainfall and that of the months of heavy rainfall. On the average of fifty years, the month having the heaviest rainfall has about 18 per cent of the annual rainfall, the month having the next lowest rainfall has about 14.5 per cent of the annual rainfall, and the next lowest month has about 12 per cent, so that the sum total of the three wettest months averages 42.44 per cent of the total annual.

The preceding studies give no evidence of any periodicity, except the daily and annual periodicities in the rainfall, and relate only to the so-called irregular or nonperiodic departures which in view of our limited knowledge we call accidental variations from normal conditions, but Hellmann now proceeds to the search for truly periodic variations.

Being given a series of monthly means for many years, if we take the general averages by months, then the difference between the month that has the highest average and the month that has the lowest average in the *mean periodic range*. If, however, we pick out the highest and the lowest monthly values for each year and take the average of the resulting extreme annual ranges we obtain the so-called aperiodic range which is larger than the periodic because the extremes of rainfall do not always occur in the same month. Thus for Königsberg, Hellmann finds a mean periodic range that is 7.5 per cent of the annual rainfall while the mean aperiodic range is 15.9; the maximum range for any year is 27.3, and the minimum is 6.4. In general the *minimum value* of the *aperiodic range* at any station is about as large as the *mean periodic range* at that station.[7]

The mean periodic amplitude is shown by a curve of monthly values, and this curve becomes flatter with elevation above sea-level, since the summer rains diminish and the winter rains increase with altitude. On those portions of the rainfall map of Germany, where 50 per cent of the rainfall at low stations occurs in the colder half of the year, we have only to ascend a short distance in order to find an inversion in the curve of annual rainfall due to the influence of the mountains, and to the fact that our stations are high enough up to allow us to recognize the existence of this phenomenon. In the German mountains, the winter rainfall is more important on the windward side than at the same level on the leeward side. But there is a plane or altitude above which the annual curve for low stations is inverted; where, consequently, the winter rainfall is more important than the summer. The summits of the eastern mountains of north Germany hardly attain to this level, since the measurements on the Schneekoppe (1603 meters) and other similar mountain tops appear to be too uncertain to fix the value of the winter rainfall. On the other hand, in the western part of north and south Germany the altitude of the plane of inversion is about 500 or 600 meters, but ten years more of observation are still needed to fix the elevation at all precisely. In the Alps, at least on the northern slopes, there seems to be no inversion.

LOCAL RAINS.

Hellmann makes a special study of heavy local rains, of

[7] The difference between extreme values is the *range;* the half-difference is the *amplitude* or the extent of the departure either way from a mean value.

short duration, the so-called "platzregen". In defining an excessive rain he differs entirely from previous European authors (Goodman, Riggenbach, Les) and says: "If, therefore, we would define platzregen we must take account simultaneously of both the duration and the intensity".[8] Hellmann modifies his earlier system of 1891 and states that in the present study he considers only those local rains whose intensity per minute and whose duration are as follows:

No.	Duration.	Intensity per minute.
	Minutes.	*Millimeter.*
1	1 to 5	1.00
2	6 to 15	0.80
3	16 to 30	0.60
4	31 to 45	0.50
5	46 to 60	0.40
6	61 to 120	0.30
7	121 to 180	0.20
8	over 180	0.10

The total number of cases occurring in each of these eight classes in north Germany between 1891 and 1902, as shown by continuous registers (Hellmann-Fuess pluviographs), is as follows:

(1) 1–5 m.	(2) 6–15 m.	(3) 16–30 m.	(4) 31–45 m.	(5) 46–60 m.	(6) 1–2 h.	(7) 2–3 h.	(8) Over 3 h.
91	357	346	167	185	319	123	151

The relation between the mean intensity, i, of each of these groups and the duration of the rain, t, in minutes is exprest approximately by the following empirical formula:

$$i = -0.311 + 3.522/\sqrt[3]{t}.$$

Inasmuch as i is the quotient of the depth of rainfall, h, divided by the time, t, therefore the above formula may be written

$$h = -0.311\,t + 3.522\,\sqrt[3]{t^2}.$$

As this formula corresponds expressly to the intense rainfalls, it represents a boundary line that separates such cases from those extraordinary rains that might be conceived of as possible, but that practically never occur. It becomes, therefore, an appropriate problem for the physical meteorologist to ascertain what physical conditions exist in the atmosphere that impose such a limit or boundary line, or to ascertain what prevents the occurrence of rainfalls more intense and over longer periods of time. A chart of the location of these heavy rains shows that they are fairly evenly distributed over the whole of Germany, but are rather more frequent in drier regions. Moreover, they occur almost exclusively in the summer or warmer half of the year, 80 per cent being in June, July, and August.

A long-continued heavy shower is known both in Germany and in America as a "cloudburst." To this phenomenon Hellmann gives a special definition, namely, "a cloudburst is a shower of at least one hour's duration, whose intensity exceeds the above-defined limits of the heaviest local rains, viz, if the cloudburst lasts an hour, the rainfall must exceed 56 millimeters; if two hours, 69 millimeters; if three hours, 90 millimeters". Hellmann quotes eight such cloudbursts, of which the most remarkable occurred at Berlin on April 14, 1902, when 143 millimeters, or 5.63 inches, fell in the course of three and one-half hours.

With regard to one very interesting question, namely, the geographical extent or the limit that should be assigned to a so-called local rain, Hellmann simply says that we must wait until we have a denser network of pluviographs, and this is true not only for Germany but for the densest networks, as in England and Barbadoes.

PERIODIC VARIATIONS.

After studying the frequency of precipitation, both diurnal and annual, Hellmann takes up the departure from uniformity which is usually exprest as an average departure per month or per year, and which may be either periodic or nonperiodic. If periodic, then some regularity should be found in the occurrence of successive wet or dry years, months, and days. After thoroly studying the accidental occurrences, Hellmann devotes a few pages to the periodic variations at 21 stations having long records. With regard to the 11-year sun-spot period he says:

> Some authors have denied any connection between rainfall and sun-spot periods, and some believe they have found such, altho these latter do not agree among themselves, since some of them find a maximum of sun spots agreeing with an excess of rainfall and others find the contrary. But these differences in the results may proceed from the fact that solar processes may have very different indirect influences on different parts of the earth. An increase or diminution of insolation in the equatorial zone must modify the energy of the general circulation of the atmosphere, whose consequences will be felt years later and in different ways in the other parts of the globe. Moreover, there will be at every station a direct local influence such that the latter may either agree with or differ from the influence that comes to it from distant equatorial regions. Thus it may happen that at one place the maximum rainfall may agree with the minimum. This idea is confirmed by the fact that in western Europe the wettest and the driest years appear to be delayed as we go northward, so that, for instance, they occur in Scotland one or two years later than in Portugal and southern Spain.

The period 1851–1900 embraces four and one-half sun-spot periods, which Hellmann counts from minimum to minimum, as is done by Hann. The rainfalls for 21 selected stations, exprest as percentages of their respective averages, are now summed up, and the totals representing all of Germany are compared with the relative sun-spot numbers of Wolf and Wolfer.[9] By taking the averages of these percentages and smoothing these by the formula $(a+2b+c)/4$, Hellmann obtains a rather regular series of numbers that indicates a double period of rainfall within a sun-spot period. The principal maximum of rainfall slightly precedes the minimum of sun spots, but the secondary maximum of rainfall coincides with the maximum of sun spots. Similar results have been attained by others, and in order better to understand the physical connection Hellmann repeats the computations for the cold and warm halves of the years 1851–1900, but the results for the two halves of the year are precisely like those for the whole year. The total amplitude of precipitation within the sun-spot period is 8 per cent in summer and 16 per cent in winter, and is therefore much smaller than the irregular variations from year to year.

With regard to Brückner's 35-year period, which was in fact first recorded by Francis Bacon in 1622, apparently as the suggestion of some earlier student, Hellmann states that he finds partial confirmation of its existence. He makes use of 24 series appropriate to this study, beginning with 1816 and ending with 1900. He compiles lustrum averages, exprest in percentages of the average rainfall during the fundamental period 1851–1900, and finds a general maximum of rainfall in the lustrum 1876–1880, and a general minimum in 1861–1865; however, this maximum is not repeated 35 years earlier at many stations, but occurs rather later, namely, 1851–1855. The minimum of 1861 recurs again 35 years earlier, in 1826–1830. Hellmann concludes that these relations between rainfall and possible cosmic influences can not have any practical importance since, when we come down to individual cases, the rules fail as often as they fit. In order to help on such investiga-

[8] The definition of excessive rain as used by the Weather Bureau was modified in the latter part of 1896 so as to take account of both time and intensity. (See Monthly Weather Review, January, 1897, Vol. XXV, pp. 13 and 21.) Doctor Hellmann's system is in substantial agreement with that of the Weather Bureau.—*A. J. H.*

[9] These are published in full in the Monthly Weather Review, April, 1902, vol. 30, p. 171.—EDITOR.

tions meteorologists can do nothing better than to secure for the whole earth the longest and most homogeneous series of observations possible.—*C. A.*

A POSSIBLE CASE OF BALL LIGHTNING.

By WILLIAM H. ALEXANDER, Local Forecaster. Dated Burlington, Vt., August 13, 1907.

During the month of July, 1907, the weather in the Champlain Valley, if not in the entire State of Vermont, was characterized by several interesting (not to say abnormal) features. Perhaps the most prominent feature was the large number of violent, and in many cases destructive, thunderstorms that occurred. A considerable number of lives was lost and much valuable property destroyed by lightning. Without doubt one of the most singular, certainly one of the most unusual, electrical phenomena known to the writer occurred at Burlington on the 2d, incident to the passage of a barometric depression from the Lake region to the lower St. Lawrence Valley during the last days of June and the first days of July. The distinctive feature of this storm was the single peal of thunder or explosion attended by what is believed to have been a case of "ball" or "globe" lightning. The "explosion" was so sudden, so unexpected, and so terrific that it startled practically the entire city, and there was a general, spontaneous rush to the window or street to see what had happened.

Effort has been made to obtain from eyewitnesses all observed details of importance relative to the phenomenon, but it appears that altho all heard the sound only a few actually saw anything. Fortunately, however, there were competent and reliable witnesses whose statements are given below in their own words.

Bishop John S. Michaud says:

I was standing on the corner of Church and College streets just in front of the Howard Bank and facing east, engaged in conversation with Ex-Governor Woodbury and Mr. A. A. Buell, when, without the slightest indication or warning, we were startled by what sounded like a most unusual and terrific explosion, evidently very near by. Raising my eyes and looking eastward along College street, I observed a torpedo-shaped body some 300 feet away, stationary in appearance and suspended in the air about 50 feet above the tops of the buildings. In size, it was about 6 feet long by 8 inches in diameter, the shell or cover having a dark appearance, with here and there tongues of fire issuing from spots on the surface resembling red-hot unburnished copper. Altho stationary when first noticed this object soon began to move, rather slowly, and disappeared over Dolan Brothers' store, southward. As it moved, the covering seemed rupturing in places and thru these the intensely red flames issued. My first impression was that it was some explosive shot from the upper portion of the Hall furniture store. When first seen it was surrounded by a halo of dim light, some 20 feet in diameter. There was no odor that I am aware of perceptible after the disappearance of the phenomenon, nor was there any damage done so far as known to me. Altho the sky was entirely clear overhead, there was an angry-looking cumulo-nimbus cloud approaching from the northwest; otherwise there was absolutely nothing to lead us to expect anything so remarkable. And, strange to say, altho the downpour of rain following this phenomenon, perhaps twenty minutes later, lasted at least half an hour, there was no indication of any other flash of lightning or sound of thunder.

Four weeks have past since the occurrence of this event, but the picture of that scene and the terrific concussion caused by it are vividly before me, while the crashing sound still rings in my ears. I hope I may never hear or see a similar phenomenon, at least at such close range.

Mr. Alvaro Adsit says:

I was standing in my store door facing the north; my attention was attracted by this "ball of fire" apparently descending toward a point on the opposite side of the street in front of the Hall furniture store; when within 18 or 20 feet of the ground the ball exploded with a deafening sound; the ball, before the explosion, was apparently 8 or 10 inches in diameter; the halo of light resulting from the explosion was 8 or 10 feet in diameter; the light had a yellowish tinge, somewhat like a candle light; no noise or sound was heard before or after the explosion; no damage was done so far as known to me.

Mr. W. P. Dodds (who was on the south side of the street, in the office of the Equitable Life Insurance Co.) says:

I saw the "ball" just before the explosion; it was moving apparently from the northwest (over the Howard Bank Building) and gradually descending; did not see it at the moment of the explosion, or afterward; no damage resulted so far as known to me.

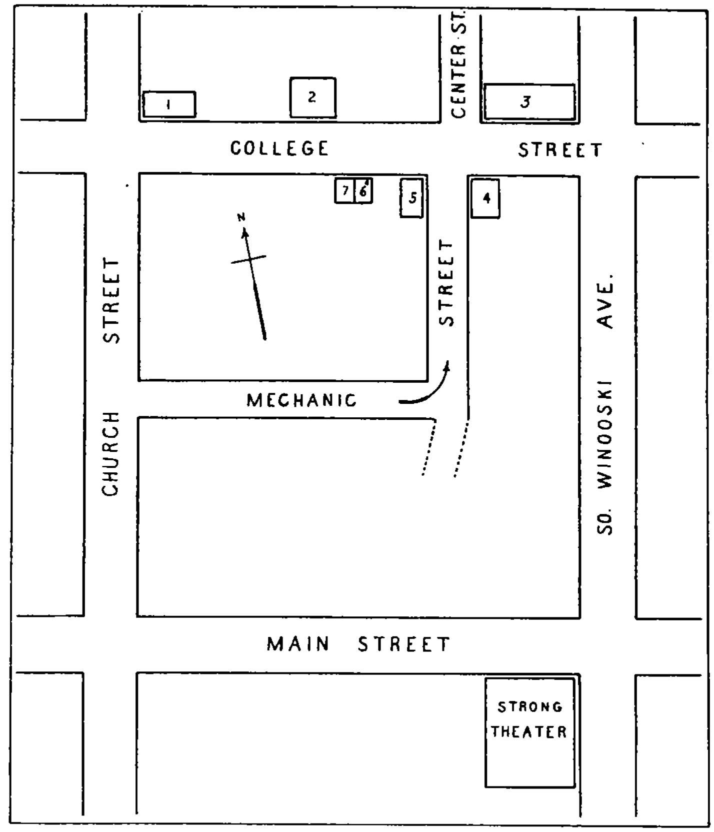

FIG. 1.—Plan of small section of Burlington, Vt., drawn (not to exact scale) to show roughly the several places mentioned in connection with the electric phenomenon of July 2, 1907. 1. Howard National Bank. 2. National Biscuit Company. 3. Hall's Furniture Company. 4. Ferguson & Adsit's store. 5. Dolan Brothers. 6. Equitable Life Insurance Company. 7. Standard Coal and Ice Company.

The following account is taken from the Burlington Daily Free Press of July 3, 1907:

A forerunner to one of the series of heavy and frequent thunderstorms that have characterized the early summer in this vicinity startled Burlingtonians yesterday just before noon. Without any preliminary disturbance of the atmosphere, there was a sharp report, the like of which is seldom heard. It was much louder in the business section of the city than elsewhere, and particularly in the vicinity of Church and College streets. People rushed to the street or to windows to learn what had happened, and when a horse was seen flat in the street in front of the Standard Coal and Ice Company's office it was the general impression that the animal had been struck by lightning and killed. This theory was not long entertained, as the horse was soon struggling to regain his feet. * * *

Ex-Governor Woodbury and Bishop Michaud were standing on the corner of Church and College streets in conversation when the report startled them. In talking with a Free Press man later in the day Governor Woodbury said his first thought was that an explosion had occurred somewhere in the immediate vicinity, and he turned, expecting to see bricks flying thru the air. Bishop Michaud was facing the east and saw a ball of fire rushing thru the air, apparently just east of the National Biscuit Company's building. Alvaro Adsit also saw the ball of fire, as did a young man who was looking out of a window in the Strong Theater Building. Another man with a vivid imagination declared that the ball struck the center of College street near the Standard Coal and Ice Company's office, knocked the horse down by the jar and then bounded up again to some undefined point in the sky. * * * The unusual disturbance was followed in a few minutes by a downpour of rain, which continued, with brief interruption, for nearly two hours.

Another described the sound as "like the tearing of new cambric". All agree that it was the most startling phenomenon of the kind ever experienced, because so unexpected.[1] The "explosion" was followed in a few minutes by a heavy

[1] This "ball of fire" may have been a distant meteor, and it will be worth while to seek for observations by distant observers about noon, Tuesday, July 2, 1907.—EDITOR.